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This work was performed by Science Applications International Corporation (Advanced Technology Systems Group); ARINC Inc. (Future Communications Group); TRW (Systems and Information Technology Group); and Crown Consulting Inc. for the National Aeronautics and Space Administration (NASA). This report presents the communications systems architecture for AATT in 2015, the interim 2007 architecture for AATT and Aviation Weather Information (AWIN), the transition from the current FAA NAS Architecture to achieve the 2015 state, and the research and development required to fill the identified technology gaps. This report provides the communications architecture framework for determining the delivery of products and services targeted for air-ground communications in the future.

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Preface

This document is the NASA AATT Task Order 24 Final Report. NASA Research Task Order 24 calls for the development of eleven distinct task reports. Each task was a necessary exercise in the development of comprehensive communications systems architecture (CSA) for air traffic management and aviation weather information dissemination for 2015, the definition of the interim architecture for 2007, and the transition plan to achieve the desired End State. The eleven tasks are summarized below along with the associated Task Order reference. The output of each task was an individual task report. The task reports that make up the main body of this document include Task 5, Task 6, Task 7, Task 8, Task 10 and Task 11, as defined below. The other tasks provide the supporting detail used in the development of the architecture. These reports are included in the appendices. The detailed user needs, functional communications requirements and engineering requirements associated with Tasks 1, 2 and 3 have been put into a relational database and provided as an electronic attachment to this Final Report.

Task Overview

Task 1: Identification of User Needs. – Our Team identified user needs and the communications system functional requirements for ATM and weather dissemination applications (AWIN) by: 1) performing a comprehensive literature/document review; 2) compiling a comprehensive list of applicable user needs; and 3) prioritizing this list into ATM and weather user needs. This data formed the basis for assessing the functional requirements. In addition to the ATM and AWIN requirements, a third category Onboard Operator/Passenger, was developed to collect additional cabin communications requirements that must be considered in the overall architecture approach.

We used the literature/document review to assimilate a comprehensive knowledge base of the existing and proposed NAS architectures, and to develop an initial description of user needs. The review included all references contained in the Research Task Order and other relevant information obtained from technical libraries and the Internet. The requirements included those for the service provider (ATM automation), the airspace user (flight deck), and the user flight planning facilities such as Airline Operations Centers (AOCs), Onboard Operator and Airline Passenger (APAX).

Task 2: Develop Communications System Functional Requirements. – Task 2 refines the set of user needs developed in Task 1 into specific communications requirements. It identified the types of message traffic, with projected message volumes. RTCA DO 237 served as the foundation for the ATM and AOC message categories defined in Task 2. The NASA report entitled Data Communications Requirements, Technology and Solutions for Aviation Weather Systems – Phase I Report, Lockheed Martin, 1999, served as the basis for sizing weather-related products. The requirements were considered in terms of domain and phase of flight.

Task 2 focused on the types of products needed to satisfy requirements, to trace more easily from user requirements to architectures. It consists of a list of communication system function requirements associated with the lists of user needs identified in Task 1.

We made this association by relating all user needs, functional requirements, and engineering requirements (Task 3) to a list of functional capabilities and NAS Services.

Task 3: Develop Communications System Engineering Requirements. - Task 3 drove the remainder of the effort, since it developed the specific engineering values from the functional requirements that were needed to assess various technological solutions. The *Operational Requirements for the ADLS* served as a foundation for this effort and was supplemented by the FARs and more recent efforts such as those conducted by Eurocontrol. This approach provided the constraints necessary to help test architectural choices posed by later tasks.

Task 4: Develop Preliminary/Candidate Communications System Architectural Concepts. – Task 4 developed a common base for architectural alternatives. The architecture is "end-to-end" and considers ground systems and avionics as well as classes of users with different types of avionics and different capabilities. Task 4 developed a common base for architectural alternatives.

In addition to requiring access to government-operated ATM and weather systems, aircraft may require access to AOC and to commercial services for information or for passenger communications. For any given mode of communication, there are likely to be multiple candidate links. By comparing the capabilities of the candidate links we identified and assessed other constraints.

Task 5: Develop 2015 AATT Architecture. – The 2015 AATT Architecture Development task use architectural concepts developed in Task 4 that were based on the communication system requirements of Task 3. For this task, we developed a comprehensive 2015 Communications System Architecture (CSA) that encompasses AATT and AWIN requirements. We identified technologies for Air-Ground and Air-Air communications, along with the standards and protocols.

The 2015 CSA represents the evolutionary establishment of the foundation for aeronautical information exchange. This foundation provides the users of the NAS with common data for all user types that provides enhanced safety through common situational awareness and provides optimum efficiency through collaborative decision making. The CSA will support general information broadcast as well as direct exchange and query of information through point-point links.

> **Task 5.1: Air-Ground and Air-Air Communications/Datalinks Technical Description**. - Based on the requirements developed in Task 3 and our investigation of known potential communications/datalink technologies, we provided a detailed end-to-end description of each of the communication/datalinks that are a part of our 2015 architecture. Architecture link types (both voice and data) that support aircraft-aircraft, aircraft-air traffic control (including control and traffic management), aircraft-flight information service, and aircraft-aircraft operations were addressed. The architecture employs the most suitable links based on the overall system performance requirements.

> **Task 5.2: Communications Architecture Network, Standards and Protocol Description.** – Based on our 2015 CSA, we provided a definition of the network standards and protocol requirements necessary to support each datalink for our

architecture to achievement of a harmonized 2015 CSA. This definition includes the identification of any interoperability requirements and standards, such as those for aeronautical flight, traffic, and commercial information. We build on existing standard work in the areas of flight and traffic information and identify the changes necessary to support our 2015 architecture.

Task 5.3: Ground-Ground Communications. - Based on the definition of our 2015 architecture, we identified unique implications for the Ground-Ground communications network infrastructure including any obstacles with respect to gaining access and transmitting data as necessary to optimize the 2015 CSA.

In many of the Concept of Operations reports published to date, there is a clear need for the implementation of a NAS-wide information sharing capability. We anticipate that this capability will be implemented in the 2012 time frame and thus should be considered as the interface for the 2015 CSA. The current concept for NAS-wide information sharing calls for a collection of local and national information services that provide for the dissemination of airport, airspace, weather, infrastructure, and active flight data (including surveillance data and flight object data) through multiple virtual private networks. This concept assumes an interface with a robust Air-Ground and Air-Air communications architecture in order to provide the desired Air Traffic Services.

Task 6: Develop AATT 2007 Architecture. - This task used the definition of the 2015 CSA from Task 5 and requirements from Task 3 to define candidate transition CSAs that lead to the 2015 CSA.

The proposed CSA for the 2007 time frame must fit with the expected evolutionary state of the NAS. In the 2007 time frame, the NAS will not yet have integrated data communications or standards. Likewise, the NAS will be in the process of making its most significant change, that of moving from the current Host-centric flight data processing to one of distributed flight objects across all ATC facilities. This change will enable the use of four dimensional flight trajectory information and will completely change the use of flight plan information as we know it today.

Task 7: Develop AWIN 2007 Architectures. – This task used the selected concept from Task 5 and requirements from Task 3 to define candidate CSAs that lead to the 2015 CSA. We identified the most promising CSAs for AWIN and further developed them to the level of detail necessary to allow the identification of technology gaps that may impede implementation. We ensured that the proposed CSAs would fit within the transition plan identified in Task 8.

We developed three 2007-state architectures that encompassed the AWIN requirements. We identified technologies for Air-Ground and Air-Air communications along with the standards and protocols that they will use. The architectures address key issues such as: (1) Data Dissemination, (2) Crew Monitoring, Presentation and Decision Aids, and (3) Weather Product Generation.

The proposed architectures must deliver accurate, timely, and precise weather data.

Task 8 (para 4.9) Develop Transition Plan. - This task developed a technical plan that detailed the transition from the current CSA to the 2015 CSA developed in Task 5. The plan demonstrated that the state architecture is credible. Our approach was to develop the transition plan based on the definition of a set of key milestones that begins with the 2015 CSA and proceeds backward in time through additional milestones. We identified elements and activities along the critical transition path, described their significance and contribution to the transition, and highlighted their contributions to the identification of key milestones. The set of required key milestones includes not only the mid-term (2007) architectures for air traffic management and aviation weather dissemination, but also those key milestones necessary to achieve and retain consistency with the evolving overall NAS Architecture (as currently defined in NAS Architecture Version 4.0). Furthermore, the transition plan for the CSA development from the current state through the 2015 state is fully consistent with the planned evolution of the NAS in terms of all its technical, programmatic, and fiscal (inter) dependencies identified in the NAS Architecture baseline.

Task 9: Characterize Current and Near term Communications System Architecture. – For this task, we documented the current CNS in sufficient detail to form a baseline for the 2007/2015 CSA development.

> **Tasks 9.1 and 9.2: Communications/Data Link Applications and Relevant Data Link Programs.** –
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> This report provides a comprehensive list that contains the system objectives, the primary benefits being derived or expected by users, the status of each program (i.e., operational system, prototype, proof-of-concept) and projected deployment, and the communication medium employed.
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> **Task 9.3: Communications/Datalink Technical Characterization.** - Using the format specified in Task 5.1 (para 4.6.1), we characterized the current and near-term data link technologies listed in SOW Paragraph 4.10.3. We gave specific consideration to identifying those characteristics that could present potential safety issues such as overall system availability and message delivery rates.
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> **Task 9.4: Networks, Standards and Protocols.** - This report maps the data link technologies identified in Task 9.3 (para 4.10.3) to the appropriate network standards and protocols and described their ability to support current and near term data links.

Task 10: Identify Communications System/Technology Gaps. – This report identifies the communication system or technology gaps for the 2007 and 2015 time frames that are not being addressed by existing or planned development or research programs. We ensured that the technology gaps are integrated into a system perspective.

Task 11: Identify Components for R&D. – The results of the previous task form the basis for recommendations for R&D. We examined each of the gaps identified in Task 10 in detail by the definition of targeted R&D efforts. Although in many cases the technology to fill the gaps exists today, certain components have not been tailored to the aeronautical communications environment. This report describes the basic technologies and solution candidates needed to implement all of the characteristics in the aeronautical environment for the planned ATM and AWIN applications and the projected Onboard Operator and passenger services.